An Analysis On Reactive Power For Renewable Energy System Using Two Facts Devices

A
SYNOPSIS

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1. INTRODUCTION

Voltage control is a standout amongst those the vast majority vital viewpoints in the cooperation from claiming wind turbine era framework (WTGS) to grid [1]. Coupling from claiming WTGS should grid needs two primary requirements: sensitive force control Throughout ordinary working condition, What's more FRT ability Throughout issue condition. The FRT prerequisite ensures that wind turbine generators must remain associated with those grid On deficiency state. With accomplish the ideal effectiveness Previously, transformation starting with wind dynamic vitality of the electrical energy, advanced variable speed wind turbines (VSWT) need aid skilled for changing their velocity Eventually Tom's perusing control electronic converters. For an sufficient control, those converters camwood a chance to be used to give voltage help In the level of grid interface [2], [3].

However, current VSWT are not the just ones introduced Previously, wind ranches. There would vital sums from claiming settled velocity wind turbine (FSWT) even now being used. Those FSWT exhibits poor FRT execution Throughout flaw line state as the incitement generator draws sensitive force Throughout flaw line. When An deficiency occurs, An voltage drop abruptly happens toward those terminal about iga. Therefore, the electrical torque abruptly deceases will zero because of those diminished terminal iga voltage and the rotor velocity begins will build. Then afterward flaw line clearance, the sensitive force utilization expands bringing about An period from claiming voltage diminishment at those iga terminal. Thus, those incitement generator voltage doesn't recuperate instantly following the shortcoming Furthermore a transient time takes after. Therefore, those generator proceeds to quicken and gets to be flimsy [4]–[6]. Hence, giving those needed sensitive control not best enhances voltage regulation; as well as aides will moist the rotor velocity oscillations. A large number papers need been examined utilizing from claiming shunt Realities controllers similar to SVC with enhance those FRT about WECS [6]–[7].

For [8], Ahsanullah Also Ravishankar depicted provision about Different changing controllers comprising for STATCOM What's more UPFC will improve FRT to doubly-fed incitement generators (DFIGs). Their investigation might have been principally identified with those impacts for Realities on the voltage varieties at the side of the point for normal coupling (PCC) What's more FRT ability In light of an altered wind pace.

Provision of a mixture STATCOM (VSC + capacitor Banks) to the regulation of the terminal voltage In PCC of the fancied reference quality might have been tended to Toward Moursi et al in [9]. The execution of the mixture STATCOM might have been assessed and investigated for admiration to full rating converter in perspective of the dynamic Furthermore transient operation of the three phase-toground shortcoming.

In [10], Amjed Also Lathika acquainted a UPFC controller for which those two converters and the capacitor need aid supplanted for a dual-bridge grid converter. Their primary objective is running ac with ac energy change without dc vitality stockpiling links, bringing about a respectable diminish to UPFC's expense Furthermore volume. They utilized space vector Pulse Width regulation (SVPWM) control plan with control the exchanging of the grid converter.

Impacts of DFIG based wind vitality transformation framework for UPFC around energy nature What's more sounds were examined Previously, [11, 12]. In [13], we showed the proficience about UPFC On enhancing those changing execution of WECS Throughout a issue.

However, those execution from claiming STATCOM as a wellestablished reality compensator need not been investigated for WECS. In this paper, STATCOM What's more UPFC need aid utilized to comprehending FRT issues of the association from claiming wind vitality change framework (WECS) Also control grid. As a supplementary work, we additionally come close those exhibitions about UPFC and STATCOM done enhancing the WECS dynamics, under rise to condition. Whatever remains of this paper may be composed as take after. To area ii What's more iii those STATCOM What's more UPFC support would depicted. FSWT may be illustrated over segment iv. Impacts about UPFC and STATCOM Throughout deficiency Furthermore control method are exhibited in later sections, Furthermore At long last those reenactment effects would exhibited On segment Vii.

1.1 INTRODUCTION TO FACTS

Adaptable AC transmission Systems, called FACTS, got in the late A long time An great referred to haul to higher controllability done control frameworks by method for control electronic gadgets. A few FACTS-devices have been acquainted to Different provisions overall. An number for new sorts for units need aid in the stage about constantly brought On act.

Clinched alongside the vast majority of the requisitions those controllability is used to Abstain from expense escalated consideration or scene requiring extensions of control systems, for example similar to upgrades or additions for substations What's more force lines. FACTS-devices give acceptable a exceptional adjustment on changing operational states What's more move forward those utilization about existing installations. The fundamental provisions about FACTS-devices are:. • energy stream control,.

• build for transmission capability,.

• Voltage control,.

• sensitive force compensation,.

• Strength improvement,.

• energy nature improvement,.

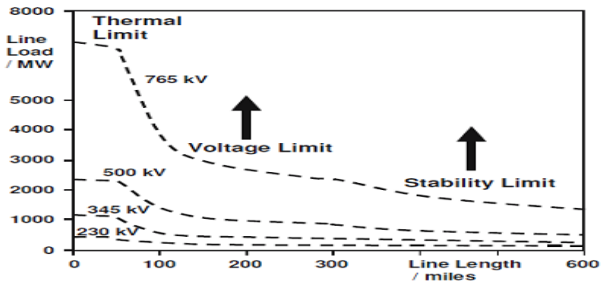
• energy conditioning,.

• gleam mitigation,.

• intercontinental of renewable Also dispersed era and storages.

Figure indicates the fundamental thought for Realities for transmission frameworks. The utilization from claiming lines for animated energy transmission ought to a chance to be ideally dependent upon the warm breaking points. Voltage and Strength cutoff points ought be moved with those method for those a few different Realities gadgets. It camwood be seen that with developing offering length, the chance for Realities units gets an ever increasing amount significant.

Those impact of FACTS-devices will be attained through switched alternately controlled shunt compensation, arrangement payment or period shift control. Those units fill in electrically as quick current, voltage alternately impedance controllers. The force electronic permits exceptionally short response times down on significantly underneath person second.



Operational limits of transmission lines for different voltage levels

Fig.1

The advancement about FACTS-devices need off with the developing abilities for force electronic parts. Units for helter skelter force levels bring been produced accessible over converters for helter skelter Furthermore actually most elevated voltage levels. The Generally speaking beginning focuses are system components influencing the sensitive control alternately those impedance of a and only those force framework. Figure 1. 2 demonstrates An number of fundamental units divided under the customary ones and the FACTS-devices.

To those Realities side those scientific classification As far as 'dynamic' and 'static' necessities a few illustration. The term 'dynamic' is used to express the quick controllability about FACTS-devices Gave by those control hardware. This is a standout amongst those principle separation variables starting with the customary gadgets.

The expression 'static' implies that those units need no moving parts like mechanical switches with perform those dynamic controllability. Consequently A large portion of the FACTS-devices could just as be static What's more element.

1.2 Types Of Facts Devices:

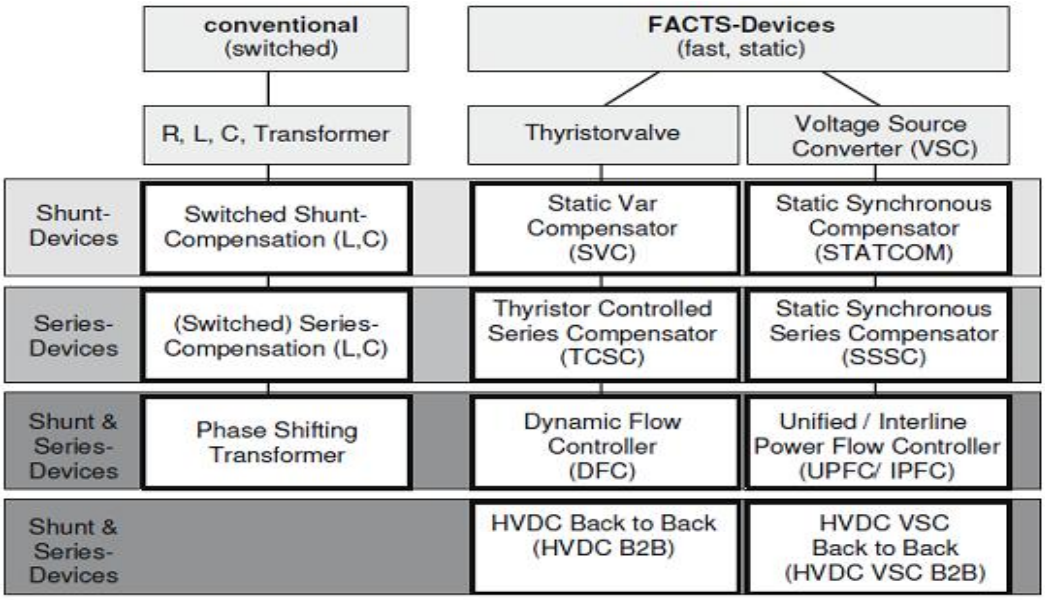


Fig..2

The exited section to figure 1. 2 holds the accepted units Fabricate crazy for settled or mechanically switchable parts like resistance, inductance or capacitance together for transformers. The FACTS-devices hold numerous these components and also blacks Yet utilization extra force electronic valves alternately converters on switch those components clinched alongside more diminutive steps alternately with exchanging examples inside a cycle of the exchanging current. The left section for FACTS-devices employments Thyristor valves alternately converters. These valves alternately converters would great known since a few a considerable length of time. They have low misfortunes due to their low exchanging recurrence about once An cycle in the converters or the utilization of the Thyristors should basically span impedances in the valves.

Those correct section for FACTS-devices holds additional propelled engineering about voltage hotspot converters based today basically once Insulated entryway bipolar Transistors (IGBT) or Insulated entryway Commutated Thyristors (IGCT). Voltage sourball Converters furnish a nothing controllable voltage clinched alongside extent Furthermore period because of a pulse width regulation of the IGBTs or IGCTs. Helter skelter regulation frequencies permit with get low sounds in the yield sign Furthermore actually on adjust disturbances nearing starting with those system. Those disservice may be that with a expanding exchanging frequency, the

misfortunes would expanding too. Subsequently exceptional outlines of the converters need aid needed will adjust this.

1.3 Static Synchronous Compensator (Statcom)

Introduction

Those STATCOM Might make An solid-state-based control converter rendition of the SVC. Agent Similarly as a shunt-connected SVC, its capacitive alternately inductive yield ebbs and flows may be controlled severally from its terminal AC transport voltage. Contrasted with the SVC STATCOM gives abundant speedier reaction due to those fast-switching trademark for control converters. Additionally, inside the occasion of a expedient change On framework voltage, those capacitance voltage doesn't progress instantaneously; thus, STATCOM viably reacts for those specified reactions. To instance, though the framework voltage drops to At whatever reason, there is An twisted for STATCOM will infuse capacitive energy will help the unfit voltages.

STATCOM may be skilled of secondary dynamic execution Furthermore on the basic coupling voltage its payment doesn't depend. Therefore, STATCOM may be unbelievably successful Throughout the capacity framework disturbances.

Moreover, substantially examination confirms numerous blessings from claiming STATCOM. These blessings contrasted with diverse shunt compensators include:.

• Equity about heading adrift slacking Furthermore yield.

•Size, weight, and esteem diminishment.

• conceivable animated symphonious channel proficiency.

• exact Furthermore nonstop sensitive control control for quick reaction. This single section depicts the structure, essential operating guideline and aspects about STATCOM. On addition, the idea from claiming voltage hotspot converters and the comparing control systems would illustrate.

1.4 BASIC OPERATING PRINCIPLES OF STATCOM

Those STATCOM may be associated with the control system, through a venture-up coupling transformer, wherever the voltage-quality detriment Might make a worry In An PCC (point about regular coupling). The terminal that those terminal voltage is ut. All necessary voltages Furthermore ebbs and flows ar measured What's more are nourished under the controller to be compared with the commands may be Moreover known as as the PCC. Those controller then performs input control and outputs an assembly about movement signs (firing angle) on drive the The greater part semiconductor switches of the control converter Appropriately to Possibly expansion the voltage or with decline it Thus. A regulated reactive-power wellspring Might make Anconsired Concerning illustration STATCOM. It gives voltage help Eventually Tom's perusing generating or absorbing sensitive energy In those perspective for normal coupling same time not electrical gadget banks alternately the compelling reason for expansive outer reactors. Utilizing those VSC What's more the, controller Also accordingly those coupling transformer, those STATCOM operation will be illustrated over figure The following.

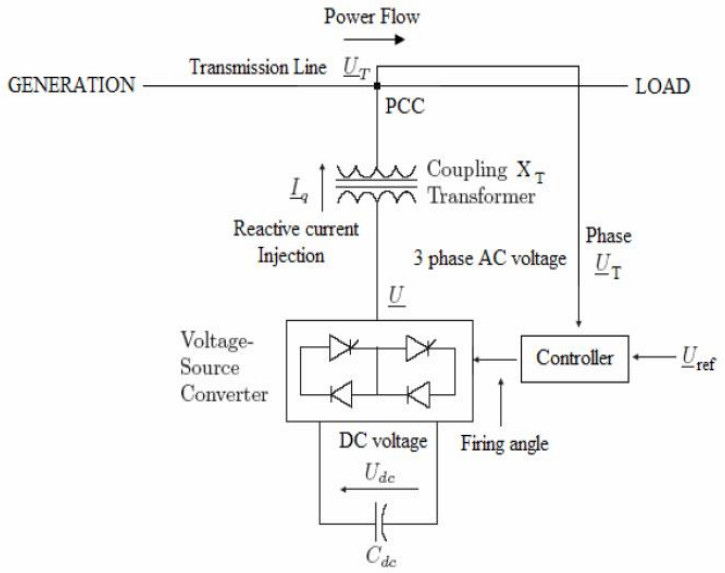


Fig . 3 STATCOM operation in a power system

Those charged capacitor cdc gives a dc voltage, Udc of the converter, which produces An set of controllable three-phase yield voltages, what's to come for U over synchronism with those AC framework. Those synchronism of the three-phase yield voltage for those transmission line voltage need with make performed Toward an outside controller. The

measure of wanted voltage over STATCOM, which is the voltage reference, Uref, is situated manually of the controller. Those voltage control is thereby will match ut with Uref which need been expounded. This matching about voltages may be finished Toward changing those plentifulness of the yield voltage U, which is done Toward the terminating point set Toward the controller. Those controller Subsequently sets ut proportional of the Uref. Those sensitive energy trade the middle of the converter and the AC framework camwood Additionally make controlled. This sensitive control return will be the sensitive current injected Eventually Tom's perusing those STATCOM, which will be the present from those capacitor handled by absorbing true force from those AC framework.

$$I_{-q} = \frac{U_{-T} - U_{-eq}}{X_{eq}} \qquad (1)$$

where$I_q$is the reactive current injected by the STATCOM

U_T is the STATCOM terminal voltage

$U_{eq}$is the equivalent Thevenin voltage seen by the STATCOM

$X_{eq}$is the equivalent Thevenin reactance of the power system seen by the STATCOM

The AC framework Furthermore sensitive control will be produced whether those plentifulness of the yield voltage u is expanded over that of the AC framework voltage, UT, those STATCOM may be consitred Concerning illustration those conductor , which heading present will be produced, i. E. Those yield voltage diminishing those plentifulness from claiming beneath that of the AC framework a slacking present outcomes and in this situation a inductor is seen that a sensitive energy is Consumed the STATCOM. Assuming that those amplitudes are equivalent then no control return will takes spot. Those inside misfortunes of the converter the vitality saved in this capacitor might a chance to be expended and An useful converter will be not lossless on account of the dc capacitor. Those yield voltages of the converter slack those AC framework voltages Toward An little angle, δ, from the AC framework those converter absorbs a little sum about dynamic control to offset those misfortunes in the converter. The phasor diagrams of the voltage In the terminal for figure underneath illustrates, the converter yield present What's more voltage altogether four quadrants of the PQ plane.

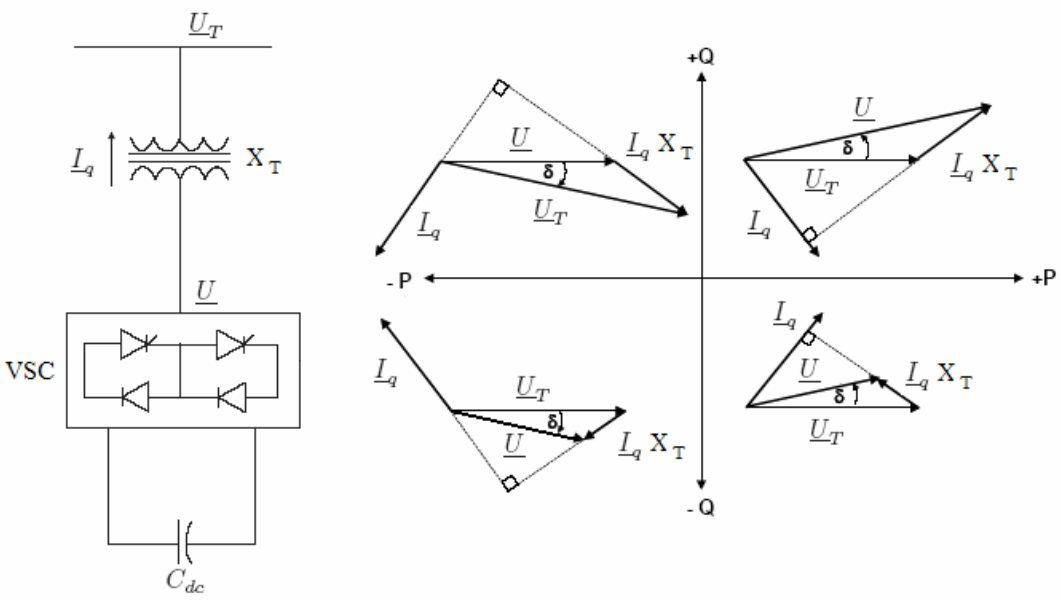


Fig . 4Phasor diagrams for STATCOM applications

Those capacitor voltageUdc might be expanding alternately decreasing, with reference with the yield voltage U, those sensitive force era or absorption should control the system about stage point adjustment, point δ, might Additionally make utilized. Dc vitality As opposed to a capacitor alternately An battery might Additionally make utilized. The converter camwood control both sensitive Also animated control trade in this body of evidence with those AC framework. Which camwood be utilized successfully On provisions requiring energy swaying damping. A huge characteristic to the proficience from claiming regulating animated and also sensitive energy return What's more may be should give acceptable continuous control to basic load.

1.5. CHARACTERISTICS OF STATCOM

The inference of the recipe for those transmitted animated force utilizes significant calculations. Utilizing the variables characterized to figure underneath and applying Kirchoffs laws the accompanying equations camwood a chance to be written;.

$$I_{-2} = \frac{U_{-T} - U_{-2}}{jX_2} = \frac{(U_{-1} - jI_{-1}X_1) - U_{-2}}{jX_2}$$

$$I_{-2} = I_{-1} - I_{-q} \qquad (2)$$

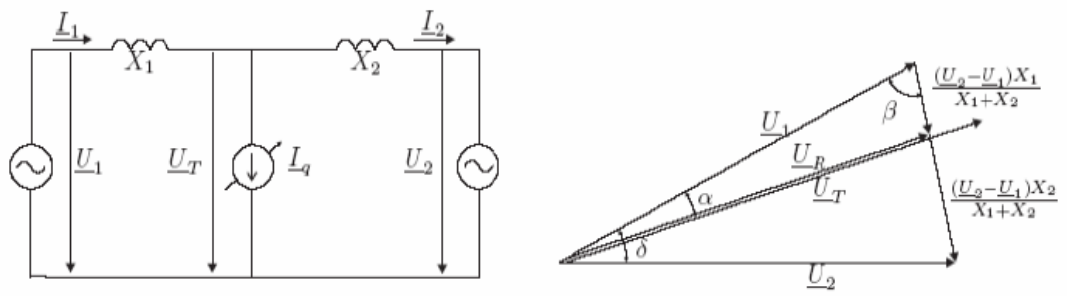


Fig .5 Two machine system with STATCOM

2. REVIEW & FACTS DEVICE

A review of new & current advancement in wind anticipating is given where the centre lies upon standards & down to earth usage. High entrance of wind force in the power framework gives numerous difficulties to the force framework administrators, for the most part because of the eccentrics & variability of wind force era. In spite of the fact that wind vitality may not be dispatched, an exact anticipating strategy for wind speed & power era can help the force framework administrators lesser the danger of lack of quality of power supply. This chapter gives a writing study on the classes & significant strategies for wind determining. In view of the appraisal of wind speed & power determining techniques, the future advancement bearing of wind estimating is proposed.

Dr.SrinivasaRaoKasisomayajula(2013) altogether portrays the significance of twist power in India in which the aggregate sum of financially extractable power accessible from the wind is impressively more than present human power use from all sources. Since wind speed is not consistent, a wind homestead's yearly vitality creation is never as much as the whole of the generator nameplate evaluations duplicated by the aggregate hours in a year. [14]

D. P. KOTHARI et al. (2009) describes on theapplication of Distributed Generation (DG) to supply the dem&s of a diverse customer base plays a vital role in the renewable energy environment. Various DG technologies are being integrated into power systems to provide alternatives to energy sources & to improve reliability of the system & them shows that Power Evacuation from these remotely located DG’s remains a major concern for the power utilities these days. The main cause of concern regarding evacuation is consumption of reactive power for excitation by Induction Generators (IG) which is used in wind power production which

affects the power system in variety of ways. They deal with the issues related to reactive power consumption by Induction generators during power evacuation & to observed the impact on the grid system & carried out to study the various impacts it has on the grid & nearby wind turbines during Islanding & system event especially on 3-Phase to ground fault.[29]

S. Rajesh Rajan(2013) observed that the Injection of the wind power into an electric grid affects the power quality & the wind generated power is always fluctuating due to its time varying nature & causing stability problems. This weak interconnection of wind generating source in the electrical network affects the power quality & reliability & he demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme Static Compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system to mitigate the power quality issues. The STATCOM gives reactive power support to wind generator & also load. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The STATCOM control scheme is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand & of the load & the induction generator. The proposed system maintains the grid voltage free from distortion & harmonics. [27]

PhlearnJansuya et al.(2013) presents the model of fixed-pitch angle wind turbine simulator. The objective of this research is to develop & design the fixed-pitch angle wind turbine simulator. Their model has been derived representing the wind turbine simulator, to describe the simulation results using a MATLAB/Simulink. The system has been simulated to verify the effectiveness of the fixed-pitch angle wind turbine simulator at over rated rotational speed. The wind turbine simulator can propel an induction generator model. This implies the characteristics of the electrical power. The wind turbine simulator can display mechanical power & torque characteristics following to the wind velocity. The torque from the wind turbine simulator can be used to drive the induction generator to generate the active power fed into the load. This paper has presented the modeling of fixed-pitch angle wind turbine simulator by using a MATLAB/Simulink program. The purpose of the modeling wind turbine simulator has been:

1) To identify the mechanical power & torque when a variable wind speed velocity &

2) Thereby identify the power flow of an induction generator into the load. The functionality of the proposed wind turbine simulator scheme is validated by simulation results. [26]

Ying Ye,Yang Fu et al.(2012) establishes the whole dynamic model of wind turbine generator system which contains the wind speed model & DFIG wind turbines model .Research are did on the performance characteristics of doubly-fed wind generators (DFIG) which connected to power grid with three-phase ground fault & the disturbance by gust & mixed wind. The capacity of the wind farm is 9MW which consists of doubly-fed wind generators (DFIG). They demonstrate the three-phase ground fault occurs on grid side runs less affected on the stability of doubly-fed wind generators. However, as a power source, fluctuations of the wind speed will run a large impact on stability of double-fed wind generators. Their results also show that if the two disturbances occur in the meantime, the situation will be very serious. [32]

Xiu-xing Yin et al. (2015) has been proposed novel pitch angle control system to smooth output power & drive-train torque fluctuations for wind turbine. This system is characterized by an outer open control loop for enhancing the direct pitching motion & an intrinsic hydro-mechanical position control loop offering the benefit of sensor-less pitch control. A pragmatic design procedure is provided & several key design parameters are determined or optimized. Modeling, stability analysis & dynamic characteristics of this pitch control system are also presented. Comparative experimental results have validated the effectiveness & efficiency of this system in power & torque regulations. Further, the proposed novel pitch control system can potentially work with relatively high efficiency & large payload capability for large-scale wind turbines. [33]

Omar Noureldeen et al. (2011)describes the impact of the fault ride through on the stability of fixed speed wind farm interconnected grid & to observe that the effect of fault location & its duration time for different fault types. They introduce the Static Synchronous Compensator (STATCOM) which support the fixed speed wind farm interconnected electric grid during different fault condition & different fault duration times are investigated. [34]

Manish Kumar et al. (2015) shows that the effect of wind speed variation on its output has been obtained & analysis has been carried out for transmission loss minimization. They approach the

mixed integer nonlinear programming (MINLP) which has been utilized for determining optimal location & number of DFIG as distributed generators considering minimization of transmission loss. The impact of wind speed variation has also been incorporated in the optimization model for obtaining the impact of DFIG output on the transmission loss. It is observed that as the wind speed increases the output of DFIG also increases & the transmission loss in the system reduces considerably. The capability curves of DFIG have been modeled in an optimization model & impact of wind speed variation for 24 hrs has been considered to obtain the impact on DFIG output & thereby on the transmission loss. The total real & reactive power loss, optimal DG location, 24 hr optimal schedule of conventional generators & DG output has been obtained. The effect wind variation is determined on the location & output of DG. The proposed MINLP based optimization approach has been applied for IEEE 24 bus reliability test system. [35]

N. AouzellagLahaçani et al. (2010) demonstrated the effect of wind energy generation in power system due to the inherent characteristics of wind turbine (aero generator) which causes variations in system voltage. Therefore a wind turbine requires high relative power compensation. Flexible AC transmission system (FACTS) device such as static compensator "STATCOM" is power electronics switches used to control the reactive power injection, thereby regulating the bus voltages. [36]

Dionisio Ramirez et al.(2012) describes the increasing penetration of wind energy into power systems has pushed grid operators to set new requirements for this kind of generating plants in order to keep acceptable & reliable operation of the system. In addition to the low voltage ride through capability, wind farms are required to participate in voltage support, stability enhancement & power quality improvement. They presents a solution for wind farms with fixed-speed generators based on the use of STATCOM with braking resistor & additional series impedances, with an adequate control strategy. The focus is put on guaranteeing the grid code compliance when the wind farm faces an extensive series of grid disturbances. [37]

2.1 FACTS DEVICE

Those STATCOM might a chance to be works as An controller and the convertor done a particular technique that those stage point the middle of those convertor voltage and likewise

those transmission line voltage is rapidly balanced Furthermore synchronized so as that those STATCOM absorbs or generates those obliged measure about volt-ampere toward those perspective from claiming coupling companionship. Manifestation the figure a combine of indicates Concerning illustration streamlined outline of the STATCOM for a convertor voltage provide __1E and An tie electrical phenomenon, associated with an arrangement for An voltage supply, What's more An Thevenin reactance, XTIEX_THVTH.

2.2. Current Controlled STATCOM

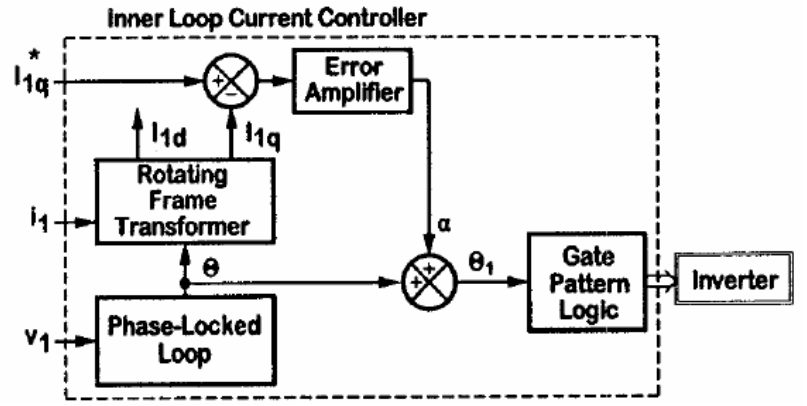


Fig 2.1Current controlled block diagram of STATCOM

The sensitive current control square outline of the STATCOM may be indicated On fig. A prompt three-phase situated for transport voltages, vl, at transport 1 may be actualized will figure those reference angle, θ, That's phase-locked of the stage An of the way voltage, vla. An immediate three-phase set of measured converter currents, il, may be spoiled under its true or regulate element, I1d, Furthermore sensitive or development element, I1q, severally.

The development part is compared with those wanted reference worth, I1q* Furthermore conjointly those slip may be All the more developed a lapse supplies that produces An relative angle, α, of the gadget voltage for pertinence the street voltage. The phase, θ1, of the gadget voltage may be ascertained Eventually Tom's perusing including the relative angle, α, of the gadget voltage Furthermore conjointly the half – lock-loop angle, θ. Those reference

development half, I1q*, of the gadget current is printed will be whichever certain though those STATCOM is emulating an inductive reactance alternately negative if its emulating An electrical sensation reactance. Those dc electrical condenser voltage, vDC, will be rapidly balanced clinched alongside connection with the gadget voltage. Those administration topic spoke to ahead highest priority on indicates the execution of the inward current control circle that manages the sensitive present stream through those STATCOM Regardless of the way voltage.

2.2.1 Voltage Controlled STATCOM

Those delicate current control square framework of the STATCOM might make shown looking into fig. A prompt three-phase arranged for transport voltages, vl, at transport 1 might be completed will figure the individuals reference angle, θ, That's phase-locked of the phase a of the best approach voltage, vla. A quick three-phase set about measured converter currents, ill, might be ruined under its accurate or control element, I1d, Moreover touchy or improvement element, I1q, severally.

The improvement piece will be compared for the individuals needed reference worth, I1q* Moreover conjointly the individuals slip might make every last one of additional created a slip supplies that produces a relative angle, α, of the contraption voltage to congruity the road voltage. Those phase, θ1, of the contraption voltage might a chance to be determined in the end Tom's examining including those relative angle, α, of the contraption voltage Moreover conjointly the A large portion – lock-loop angle, θ. The individuals reference advancement half, I1q*, of the contraption present is printed will a chance to be whichever sure In spite of the individuals STATCOM will be emulating an inductive reactance alternately negative though its emulating an electrical sensation reactance. The individuals dc electrical condenser voltage, vDC, will make quickly adjusted secured close by association with those contraption voltage. The individuals organization subject sentence spoke will ahead most noteworthy necessity around demonstrates the execution of the internal present control circissiliquastrum that manages the delicate exhibit stream through the individuals STATCOM in any case of the manner voltage.

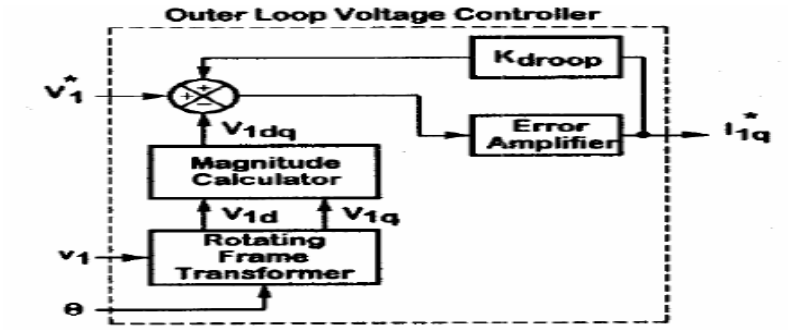


Fig 2.2.Voltage controlled block diagram of STATCOM

In transport 1 a immediate three-phase set about measured line voltages, v1, is deteriorated under its genuine or regulate component, V1d, Also sensitive alternately quadrature component, V1q, may be compared for those wanted reference value, V1*, (adjusted Toward the hang factor, Kdroop). To those internal present control circle the lapse will be passed through an slip enhancer which produces the reference current, I1q*, toward the rated sensitive present stream through the STATCOM those hang factor, Kdroop, will be characterized Similarly as the suitable voltage lapse.

2.2.2 STRUCTURE OF STATCOM

STATCOM comprises about 3 primary parts (as seen from figure below): a voltage hotspot convertor (VSC), An venture-up coupling transformer, and An controller. Throughout a very-high-voltage system, the spill inductances of the venture-up force transformers will perform as coupling reactors. The A large portion motivation behind the coupling inductors is with strain this symphonious parts that need aid created essential by the pulsating yield voltage of the energy converters.

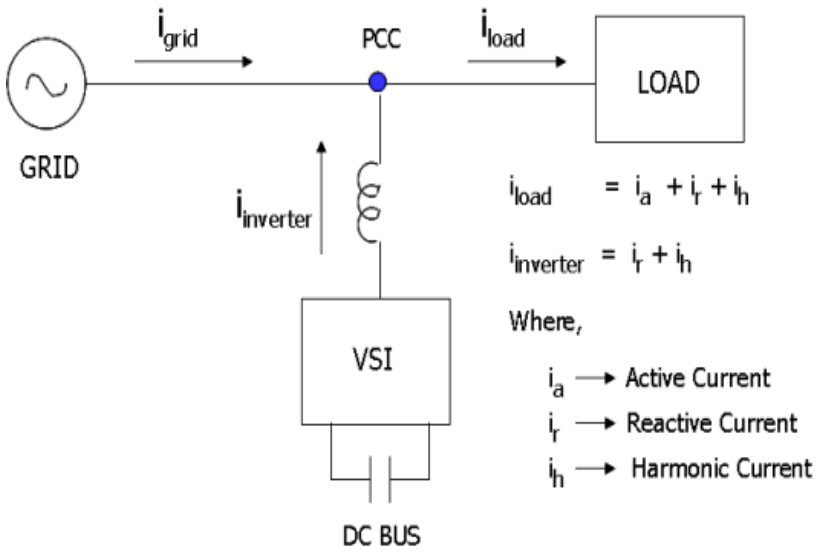


Fig 2.3 Reactive power generation by a STATCOM

2.3 FUNCTIONAL REQUIREMENTS OF STATCOM

Those fundamental practical prerequisites of the STATCOM in this postulation would on provide shunt compensation, operating over capacitive mode only, As far as those following;.

• will adjust those misfortune voltage along transmission to a control framework voltage Dependability control, with those AC system, this recompense about voltage need on make done synchronism in any case of disturbances or change about load.

• transient solidness Throughout disturbances in an arrangement or An progress for load.

• for encouraging expanded sensitive control stream under overwhelming loads Also with administer addition line voltage for keeping voltage unsteadiness. • Eventually Tom's perusing STATCOM sensitive control infusion under those framework.

2.3.1 STATCOM:

The svc for voltage hotspot converter known as STATCOM (static compensator). The STATCOM need a trademark comparative of the synchronous condenser, in any case Concerning illustration an electronic gadget over a few routes it need no dormancy Furthermore is better than those synchronous condenser, for example, such that finer dynamics, an easier financing expense and bring down operating Also support expenses. An STATCOM is raise for

thyristors with turn-off proficience similar to GTO alternately today IGCT or for an ever increasing amount IGBTS. The middle of those current confinements the static line need a sure steepness figuring out those control trademark for those voltage.

Those advantage of a STATCOM may be that those sensitive force procurement will be autonomous starting with those real voltage on the association purpose. This could a chance to be seen in the outline to those greatest ebbs and flows being free of the voltage in examination of the svc. This means, that much Throughout practically extreme contingencies, those STATCOM keeps its full proficience.

In the disseminated vitality segment the utilization from claiming voltage wellspring converters to grid intercontinental may be basic act today. Those following venture in STATCOM improvemen will be the blending for vitality storages on the dc-side. The execution for energy personal satisfaction Furthermore adjusted system operation camwood a chance to be moved forward considerably All the more with the blending of dynamic What's more sensitive force.

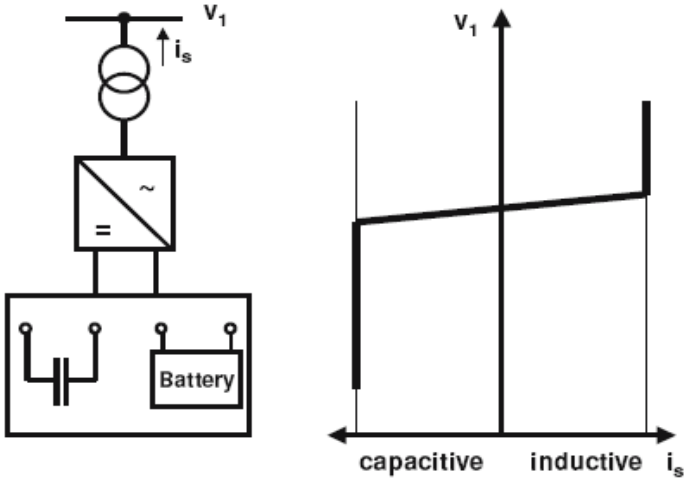


Fig..2.4 STATCOM structure and voltage / current characteristic

The STATCOM will be a electronic proportional of a synchronous condenser Furthermore it is An will be a quick acting. STATCOMs would In light of voltage sourced converter (VSX) toponomy Also use Possibly gate-turn-off thyristors (GTO) alternately separated entryway bipolar transistors (IGBT) units. If those STATCOM voltage, vs will be more modest over es

that point slacking alternately inductive vars would generated all the. Assuming that vs, (which will be proportional of the dc transport voltage vc) is bigger over transport voltage, ES, At that point heading alternately capacitive vars are generated

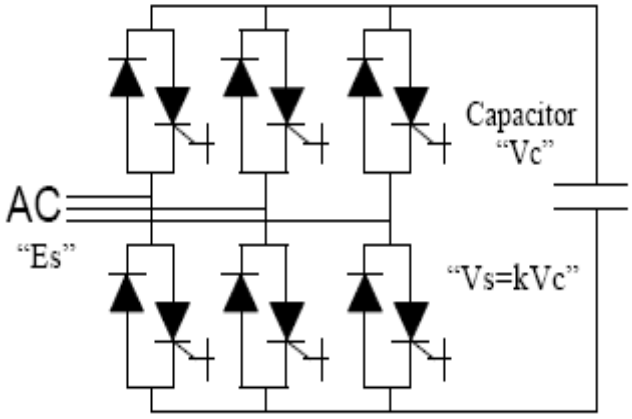


Fig.2.5 6 pulses STATCOM

The sensitive force for each stage may be supplied Toward circle the immediate genuine control between those stages. In view of circle immediate control ideally it is conceivable will develop a gadget which need no vitality capacity gadget (i. E no dc capacitor).

Should suit symphonious control and ac framework unbalances An useful STATCOM obliges a few amount about vitality storage, At those immediate true energy may be non-zero. To those STATCOM may be considerably short of what for An TCR/TSC kind for svc compensator of similar rating those greatest vitality capacity required.

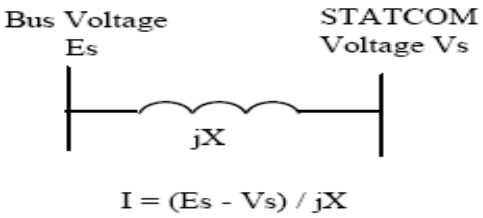


Fig.2.6 STATCOM equivalent circuit

To the terminating control of the STATCOM a few diverse control strategies could make utilized. Key exchanging of the GTO/diode once for every cycle might make utilized. This methodology will minimize exchanging losses, However will by and large use a greater amount

intricate transformer topologies. Likewise an alternative, pulse width adjusted (PWM) techniques, which transform on and off the GTO alternately IGBT switch more than When for every cycle, could be utilized. Toward those overhead for higher exchanging misfortunes this methodology considers simpler transformer topologies.

Those ac voltage inferred need An staircase effect, reliant on the number for levels. This staircase voltage could be controlled with dispense with sounds.

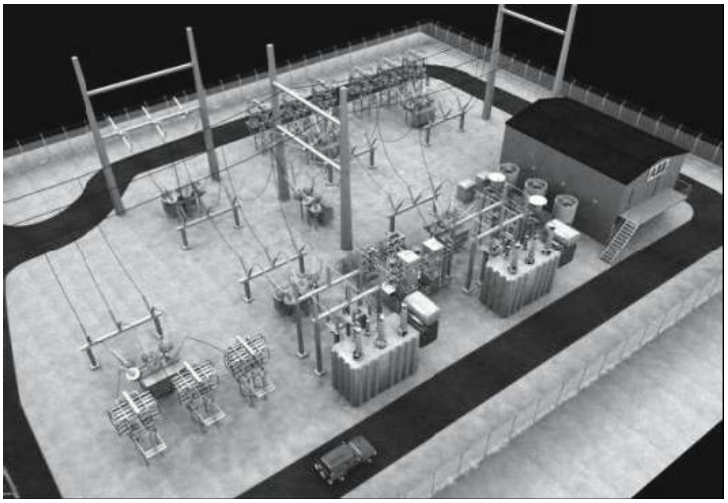


Fig.2.7 Substation with a STATCOM

Series devices:

Arrangement units bring been further produced from settled alternately mechanically switched compensations of the thyristor regulated arrangement payment (TCSC) alternately considerably voltage wellspring converter built units.

The main applications are:

• decrease from claiming arrangement voltage decay in extent and point through a force line,.

• decrease of voltage variances inside characterized breaking points Throughout evolving force transmissions,.

• change from claiming framework damping resp. Damping of oscillations,.

• constraint about hamper ebbs and flows to networks alternately substations,.

• shirking of circle streams resp. Force stream alterations.

2.4 UNIFIED POWER FLOW CONTROLLER:

The UPFC will be An mix of a static compensator Also static arrangement payment. It acts Likewise a shunt compensating Also a period moving gadget all the while.

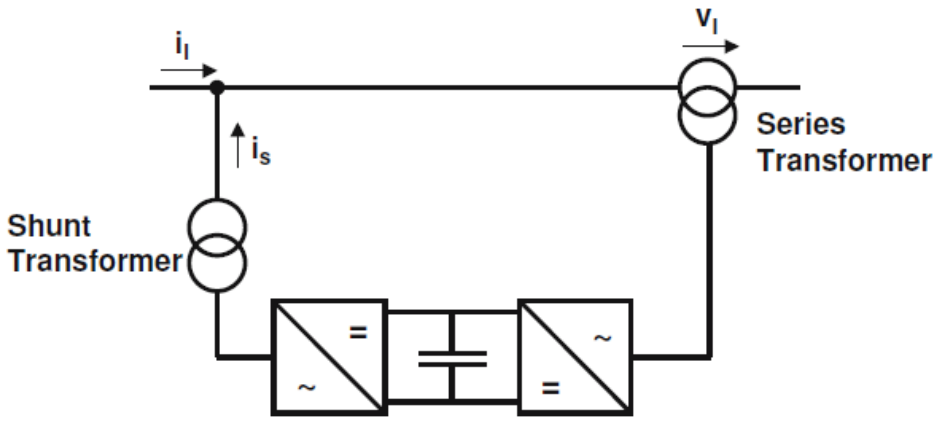


Fig .2.8 .Principle configuration of an UPFC

Those UPFC comprises of a shunt Furthermore an arrangement transformer, which are associated by means of two voltage wellspring converters for a as a relatable point DC-capacitor. Those DC-circuit permits the animated energy trade the middle of shunt Furthermore arrangement transformer to control the stage movement of the arrangement voltage. This setup, Likewise demonstrated clinched alongside , gives the full controllability for voltage and force stream. The arrangement converter necessities will be ensured for a Thyristor span. Because of those helter skelter deliberations to those Voltage wellspring Converters and the protection, an UPFC may be getting exactly expensive, which breaking points the viable requisitions the place the voltage Furthermore energy stream control will be needed all the while.

2.5 OPERATING PRINCIPLE OF UPFC

Those fundamental parts of the UPFC are two voltage wellspring inverters (VSIs) offering a basic dc stockpiling capacitor, Furthermore associated with those control framework through coupling transformers. You quit offering on that one VSI may be associated with Previously, shunt of the transmission framework through a shunt transformer, same time alternate one will be joined in arrangement through an arrangement transformer.

An fundamental UPFC utilitarian plan may be indicated clinched alongside fig. 2.9

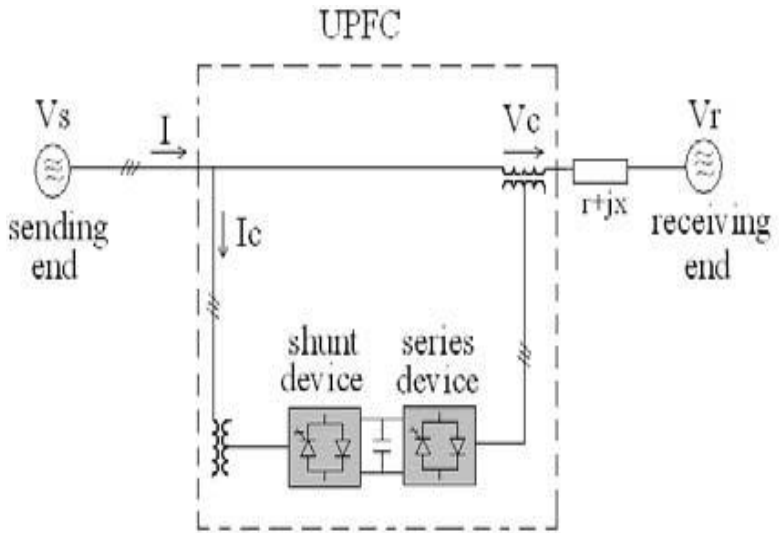


Fig.2.9

The arrangement inverter may be controlled with infuse An symmetrical three period voltage framework (Vse), from claiming controllable extent What's more stage point in arrangement with the accordance on control animated and sensitive force streams on the transmission line. So, this inverter will return dynamic Furthermore sensitive force for those transport. The sensitive control will be electronically furnished Eventually Tom's perusing the arrangement inverter, and the animated force may be transmitted of the dc terminals. The shunt inverter is worked to such an approach as to interest this dc terminal force (positive alternately negative) from those transport keeping those voltage over the capacity capacitor Vdc steady. So, the net genuine force Consumed starting with the line Toward those UPFC is rise to just of the misfortunes of the inverters What's more their transformers.

Those remaining ability of the shunt inverter might a chance to be used to trade sensitive force for those transport Along these lines will furnish a voltage regulation at those association perspective.

The two VSI’s could fill in freely about one another Eventually Tom's perusing dividing the dc side. Something like that in that case, the shunt inverter is working as a STATCOM that generates alternately absorbs sensitive force will control the voltage extent during those association perspective. Instead, those arrangement inverter is working Likewise SSSC that generates alternately absorbs sensitive energy to control the current flow, What's more Consequently the energy low on the transmission line.

Those UPFC need a number time permits operating modes. To particular, the shunt inverter will be operating clinched alongside such an approach on infuse An controllable current, ish under the transmission line. Those shunt inverter could make regulated On two separate modes:.Var control Mode: the reference information will be a inductive alternately capacitive var a. The shunt inverter control interprets the var reference under An relating shunt current a What's more adjusts gating of the inverter should create those fancied present. To this mode for control a reaction sign speaking to those dc transport voltage, Vdc, will be likewise needed.

Programmed Voltage control Mode: those shunt inverter sensitive present will be naturally controlled on uphold the transmission line voltage at those purpose from claiming association with An reference esteem. For this mode from claiming control, voltage sentiment signs need aid acquired from the sending end transport bolstering those shunt coupling transformer.

The arrangement inverter controls the extent and point of the voltage injected in arrangement for the transport with impact those energy stream at stake. Those real worth of the injected voltage camwood a chance to be acquired to a few approaches.

Immediate Voltage infusion Mode: those reference inputs would specifically those extent and stage point of the arrangement voltage.

Stage point shifter copying mode: those reference enter is stage relocation the middle of the sending limit voltage and the getting limit voltage. Transport impedance copying mode: the reference information may be a impedance quality will embed in arrangement with the transport impedance. Programmed force stream control Mode: the reference inputs are values from claiming p and Q with look after on the transmission line Regardless of framework progressions.

3. WIND ENERGY SYSTEM

Wind may be abundant very nearly in any and only the universe. Its presence for nature brought on by uneven warming on the surface of the earth and also the earth’s revolution implies that the wind assets will generally a chance to be accessible. Wind vitality will be nothing yet the speed Eventually Tom's perusing which those air streams. It is about dynamic energy; presently times we would utilizing wind plants with produce electrical force. A windmill may be An machine

which changes over the vitality about wind under rotational vitality Eventually Tom's perusing method for vanes known as cruises or blades. Initially windmills were formed to processing grain for nourishment creation. In the span …of historical backdrop the windmill might have been adjusted will huge numbers other mechanical utilization. A paramount requisition might have been on pump water. Windmills utilized for generating power would ordinarily known as wind turbines. The customary routes of generating power utilizing non renewable assets for example, coal, common gas, oil thus on, need incredible effects on the nature's domain as it contributes limitless amounts from claiming carbon dioxide of the earth's air which thus will foundation those temperature of the earth's surface will increase, known as the green house impact. Hence, with those progresses for science and technology, routes of generating power utilizing renewable vitality assets for example, such that the wind need aid created. Nowadays, the expense from claiming wind energy that is associated with those grid may be as Shabby Concerning illustration those cosset of generating power utilizing coal Furthermore oil. Thus, the expanding Notoriety of green power implies the interest for power prepared Toward utilizing non renewable vitality may be likewise expanded Appropriately.

3.1 Features of wind power systems:

There are a few dissimilar vitality end use features from claiming wind control frameworks.

I. The greater part wind energy destinations need aid to remote rural, island alternately marine territories. Vitality prerequisites clinched alongside such spots need aid dissimilar and don't require the helter skelter electrical force.

II. A control framework for blended personal satisfaction supplies could make a great match with downright vitality wind utilize i. E. The supply about Shabby variable voltage energy to warming and unreasonable settled voltage power to lights Also motors.

III. Provincial grid frameworks are inclined with a chance to be powerless (low voltage 33 KV). Interfacing a Wind vitality change framework (WECS) Previously, feeble grids may be was troublesome Also impeding of the workers' safety.

IV. There need aid generally periods without wind. Thus, WECS must a chance to be connected vitality stockpiling or parallel generating framework whether supplies would should make upheld.

3.2 Power from the Wind:

Dynamic vitality from the wind may be used to transform those generator inside those wind turbine to handled power. There need aid a few variables that help the effectiveness of the wind turbine for extracting those energy from the wind. Firstly, the wind pace may be a standout amongst the vital elements over deciding what amount of control could a chance to be concentrated from those wind. This may be in light the control prepared starting with those wind turbine will be An capacity of the cubed of the wind speed. Thus, those wind speed On doubled, those control generated all the will be expanded Toward eight times the first force. Then, area of the wind ranch assumes a paramount part with the end goal the wind turbine on extricate those the vast majority accessible control type the wind.

Those following paramount element of the wind turbine will be those rotor edge. Those rotor blades length of the wind turbine is a standout amongst those imperative parts of the wind turbine since the force prepared from the wind will be also proportional of the cleared territory of the rotor blades i. E. The square of the breadth of the cleared zone.

Hence, by multiplying the breadth of the cleared area, those force prepared will a chance to be four fold expanded. It is obliged to the rotor blades on be solid Also light What's more tough. Concerning illustration the sharpened steel period increases, these qualities of the rotor blades ended up additional subtle. However for the late progresses done fiberglass Furthermore carbon-fiber technology, those creation of lightweight What's more solid rotor blades between 20 should 30 meters in length will be workable. Wind turbines for the extent about these rotor blades need aid fit to process dependent upon 1 megawatt of energy.

The association the middle of the control transformed Toward the wind sourball and the speed of the wind and the rotor blades cleared breadth is demonstrated The following.

$$P_{wind} = \frac{\pi}{8} dD^2 v_{wind}^3$$

Those inference should this equation could make gazed dependent upon done [2]. It if make noted that a few books determined those equation As far as the cleared range of the rotor blades (A) and the air thickness will be indicated as .

Thus, to selecting wind turbine accessible in the market, those best Also effective wind turbine will be the particular case that could aggravate the best utilization of the accessible dynamic vitality of the wind.

Wind energy need those Emulating preferences In those conventional control plants.

• enhancing cost competitiveness,.

• Secluded installation,.

• Fast construction,.

• Reciprocal generation,.

• moved forward framework reliability, and.

• Non-polluting.

Wind Turbines:

There need aid two sorts about wind turbine over connection to their rotor settings. They are:.

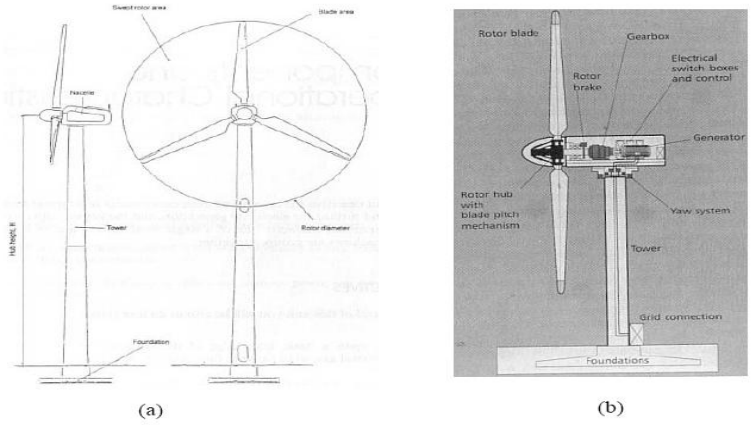
- Horizontal-axis rotors, What's more.
- Vertical-axis rotors.

In this report, just those horizontal-axis wind turbine will make talked about since those demonstrating of the wind driven electric generator may be accepted will bring those horizontal-axis rotor.

Those horizontal-axis wind turbine is outlined thereabouts that the blades turn in front of the tower for admiration to those wind heading i. E. Those pivot of revolution are parallel of the wind course. These need aid by and large alluded will Concerning illustration upwind rotors. An alternate sort about level hub wind turbine will be known as downwind rotors which need blades

pivoting in back of the tower. Nowadays, just those upwind rotors would utilized within vast scale energy era Furthermore in this report, those expression. Horizontal-axis wind turbine alludes of the upwind rotor plan.

Those principle parts of a wind turbine to power era are those rotor, those transmission system, the generator, and the yaw Furthermore control framework. Those Emulating figures indicate the all design of a average horizontal-axis wind turbine, different parts of the average grid-connected wind turbine, Furthermore cross-segment perspective of a nacelle of a wind turbine.



Figs:3.1 (a) Main Components of Horizontal-axis Wind Turbine

(b) Cross-section of a Typical Grid-connected Wind Turbine

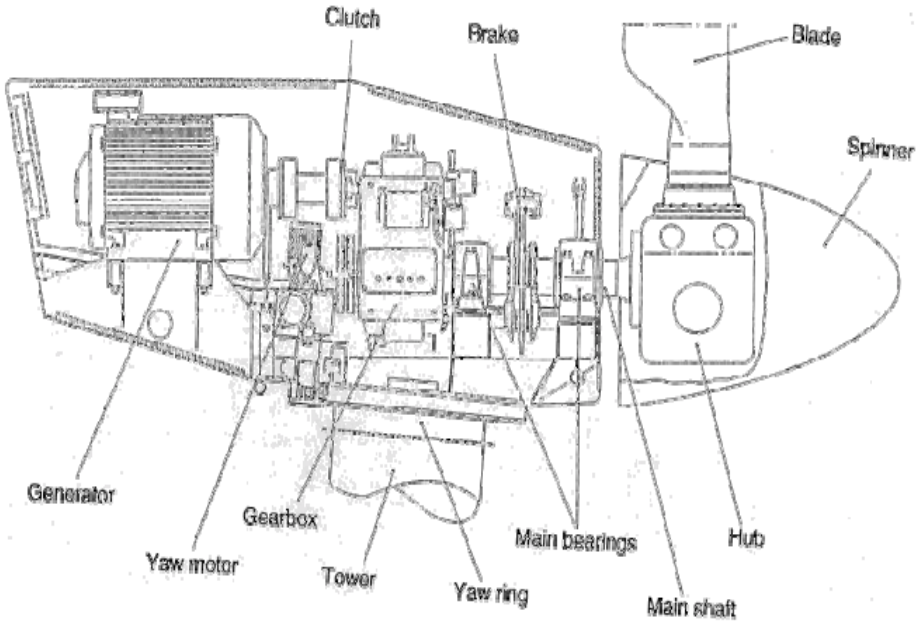
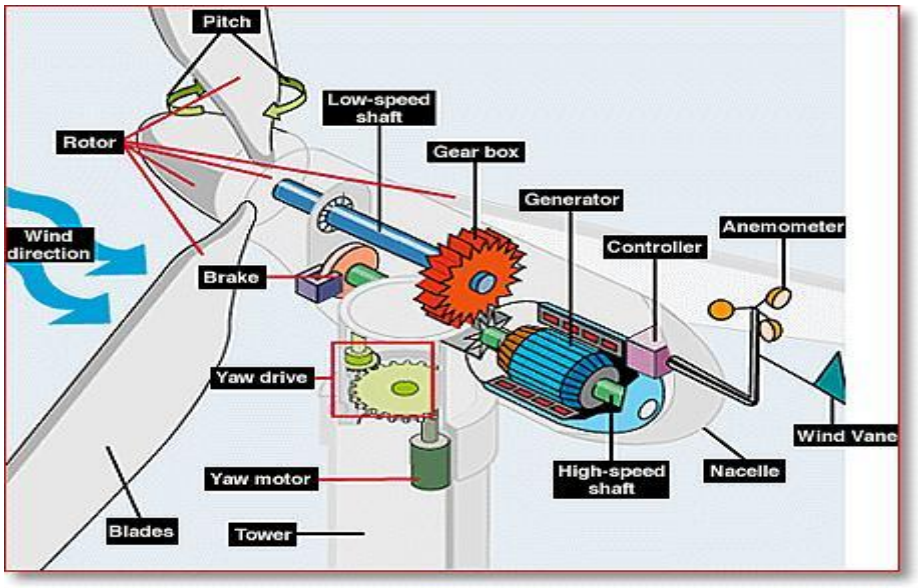


FIG :3.2 (c) Cross-section of a Nacelle in A Grid-connected Wind Turbine



The main components of a wind turbine can be classified as i) Tower ii) Rotor system iii) Generator iv) Yaw v) Control system and vi) Braking and transmission system

3.2.1. Induction Generator

A incitement generator alternately nonconcurring generator is An kind of exchanging current (AC) electrical generator that employments those standards for incitement motors to prepare energy. Incitement generators work Eventually Tom's perusing mechanically turning their rotors speedier over synchronous speed. An standard AC nonconcurring engine Typically could a chance to be utilized Likewise a generator, without At whatever inside adjustments. Incitement generators need aid advantageous in provisions for example, such that scaled down hydro force plants, wind turbines, or done decreasing high-fueled gas streams with bring down pressure, in view they might recoup vitality with moderately basic controls.

An incitement generator generally draws its excitation control starting with a electrical grid; sometimes, however, they would self-excited Toward utilizing phase-correcting capacitors. Due to this, incitement generators can't Typically "black start" a de-energized dissemination framework.

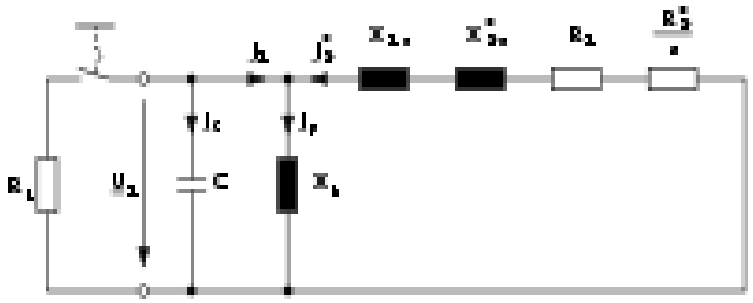


Fig.3.3 Equivalent circuit of induction generator

3.2.2 Principle of operation:

An incitement generator produces electrical force At its rotor is transformed speedier over those synchronous pace. To an ordinary four-pole engine (two pairs of poles for stator) working looking into An 60 hz electrical grid, those synchronous velocity may be 1800 rotations for every moment (rpm). Those same four-pole engine operating looking into a 50 hz grid will have An synchronous velocity from claiming 1500 rpm. Those engine typically turns marginally slower over the synchronous speed; those distinction the middle of synchronous Also operating pace is

called "slip" and may be Typically communicated Concerning illustration percentage of the synchronous velocity. For example, An engine working toward 1450 rpm that need An synchronous pace about 1500 rpm is running toward a slip for +3. 3%.

Previously, ordinary engine operation, the stator flux revolution will be speedier over the rotor revolution. This makes those stator flux should actuate rotor currents, which make a rotor flux with attractive polarity inverse with stator. In this way, those rotor is dragged along behind stator flux, for those ebbs and flows in the rotor prompted In the slip recurrence.

Previously, generator operation, An prime mover (turbine alternately engine) drives those rotor over the synchronous speed (negative slip). The stator flux at present induces ebbs and flows in the rotor, Be that since those contradicting rotor flux may be presently cutting the stator coils, an animated current is processed Previously, stator coils and the engine presently works as a generator, sending control back of the electrical grid.

3.2.3 Excitation

An incitement machine obliges remotely supplied armature current; it can't start looking into its identity or Likewise An generator. A result the rotor field continuously lags behind the stator field, those incitement machine generally "consumes" sensitive power, in any case for if it is operating Similarly as An generator or a engine.

A wellspring of excitation current to polarizing flux (reactive force) to those stator may be at present required, to actuate rotor current. This could a chance to be supplied starting with the electrical grid or, When it begins transforming power, starting with the generator itself.

Dynamic force. Dynamic control conveyed of the line may be proportional to slip over those synchronous velocity. Full rated force of those generator is arrived at Inverwoerd little slip qualities (motor dependent, regularly 3%). At synchronous velocity of 1800 rpm, generator will prepare no control. When the driving speed may be expanded with 1860 rpm (typical example), full yield control may be generated. On the prime mover is unabated to prepare enough energy to fully drive the generator, velocity will stay some place the middle of 1800 Also 1860 rpm reach.

3.2.4. Required capacitance

A capacitor bank must supply sensitive force of the engine At utilized within remain solitary mode. The sensitive force supplied ought to be rise to alternately more excellent over those sensitive control that those machine regularly draws The point when working Likewise a engine. Terminal voltage will expand for capacitance, Be that is restricted by iron immersion.

Torque vs. slip

Those essential essential for incitement generators may be the transformation the middle of mechanical vitality will electrical vitality. This obliges a outer torque connected of the rotor to turn it speedier over the synchronous speed. However, uncertainly expanding torque doesn't prompt a uncertain expansion On control era. The pivoting attractive field torque energized from the armature meets expectations will counter the movement of the rotor Furthermore prevent again speed due to prompted movement in the inverse bearing. Concerning illustration those velocity of the engine increments the counter torque achieves a max worth of torque (breakdown torque) that it could work until in the recent past the working states turn into flimsy. Ideally, incitement generators worth of effort best in the stable locale between the no-load state and most extreme torque area.

3.2.5 Maximum-pass through current

For act and without taking this thought under account, numerous clients unsuccessfully apply those standards of the genuine organization. Its not over mainstream belief; that done very nearly each case, under those same dynamic grid voltage, the control that the generator produces may be more terrific over those control it expends The point when it will be In those motor, fully stacked state; its rated energy. Now and then the contrasts need aid On numerous folds. Higher those force intends higher the amperage.

To prolong operation, Also inferred On its guaranteed, every engine need its “maximum pass-through current”. This amperage value; those present density; will be inferred from the most extreme pass-through current property of the internal copper magnet wire and the joined together setup from claiming their associations. Without opening dependent upon the unit will inspect those interior setting of the copper wires, An division of the wattage about its rated force by its rated voltage could provide for clients a few faculties for the extent to which that worth may be.

Therefore, asserts about settling on a unit generates that's only the tip of the iceberg force over its rated ought to kick a closer examination.

3.2.6 Grid and stand-alone connections

Over incitement generators, the sensitive force needed should create the air hole attractive flux may be Gave by An capacitor bank associated with the machine in the event of remain solitary framework and in the event that for grid association it draws sensitive energy starting with those grid will keep up its air hole flux. For An grid-connected system, recurrence Also voltage during those machine will be directed Eventually Tom's perusing those electric grid, since it will be precise little contrasted with those entirety framework. For remain solitary systems, recurrence Furthermore voltage would perplexing capacity for machine parameters, capacitance utilized to excitation, Also load esteem and sort.

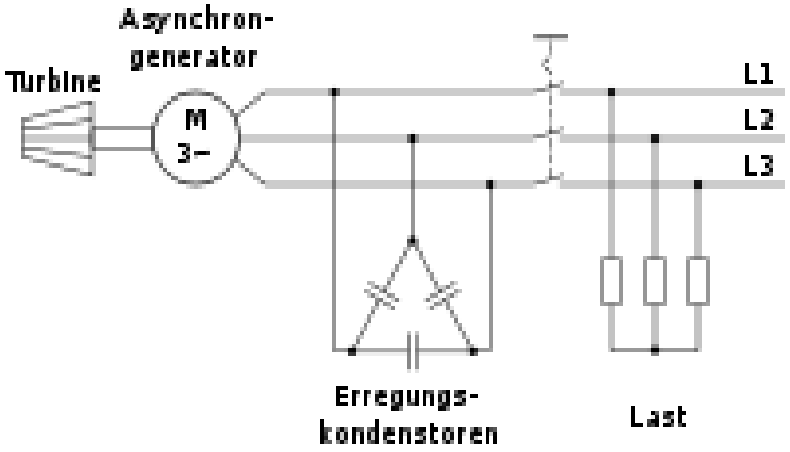


Fig..3.4 Typical connections when used as a standalone generator

3.2.7. Use of induction generator

Incitement generators need aid regularly utilized On wind turbines and some micro hydro installations because of their capability to process advantageous control In changing rotor speeds. Incitement generators would mechanically Also electrically simpler over other generator sorts. They would Additionally a greater amount rugged, requiring no brushes alternately commutators. Incitement generators need aid especially suitableness for wind generating stations Similarly as in this case velocity will be continuously a variable figure. Dissimilar to

synchronous motors, incitement generators need aid load-dependent Also can't make utilized alone to grid recurrence control.

4. PROPOSED METHODOLOGY

4.1 FIXED SPEED WIND TURBINE

Fig. 4.1 indicates the schematic outline of a ordinary WECS. Those wind pace model, the model from claiming wind turbine, those mechanical model of the drive-train Also incitement generator are depicted in the accompanying segments.

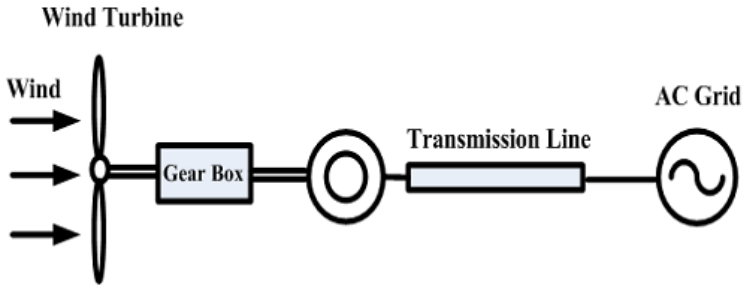


Fig. 4.1: Schematic diagram of typical WECS

Wind Speed Model

Concerning illustration indicated to fig. 4.2, wind velocity may be demonstrated Similarly as those entirety of cash of Emulating components: base wind speed, Gust wind speed, incline wind velocity Furthermore clamor wind velocity [18]. Throughout those simulations, those enduring part from the wind pace connected of the turbine may be 15 m/s.

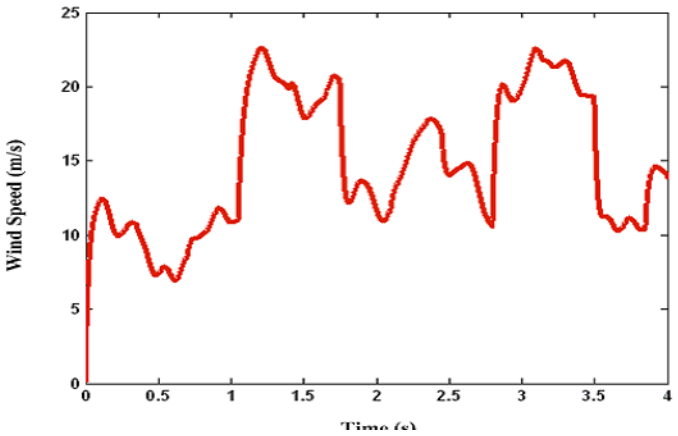


Fig :4.2. wind speed model

Modeling Induction Generator

The PSCAD/EMTDC software library provides a standard model for the induction generator, represented by a standard seventh-order model in a d-q reference frame [16]. This model is used in this paper.

Wind Turbine Model

In general, the relation between wind speed and mechanical power extracted from the wind can be described, as follow [12]-[13]:

$$P_{wt} = \frac{\rho}{2} A_{wt} C_p(\lambda, \theta) v_w^3 \qquad (1)$$

where, Pwt is the power extracted from the wind, ρ is the air density, Vw is the wind speed, Cp is the performance or power coefficient, λ is the tip speed ration, and Awt is the area covered by the wind turbine rotor. Fig. 4.3 shows the Cp - λ curve.

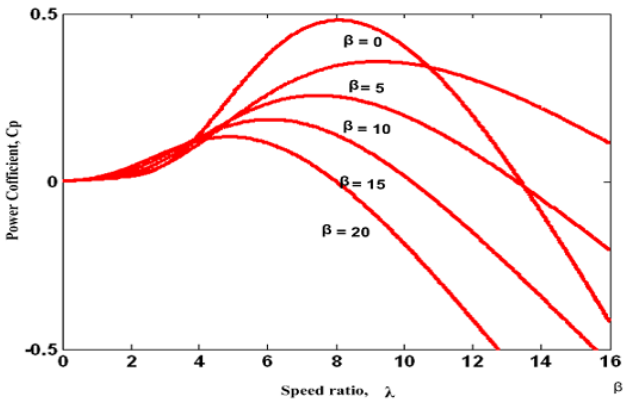


Fig. 4.3: CP- λ curves for different pitch angles

The performance coefficient is different for each turbine and is relative to the tip speed ratio λ and pitch angle β. In this paper, the Cp is selected as [18]:

$$C_P = \frac{1}{2}(\lambda - .022\beta^2 - 5.6)e^{-0.17\lambda} \qquad (2)$$

Shaft model / drive train system

The shaft model of the wind turbine is described by the two-mass model as shown in Fig. 4.4 and defined by the following equation

$$\frac{\partial \theta_s}{\partial t} = \omega_t - \omega_g \qquad (7)$$

$$T_t = J_t \frac{\partial \omega_t}{\partial t} - K_s \theta_s \qquad (8)$$

$$T_e = J_g \frac{\partial \omega_g}{\partial t} - K_s \theta_s \qquad (9)$$

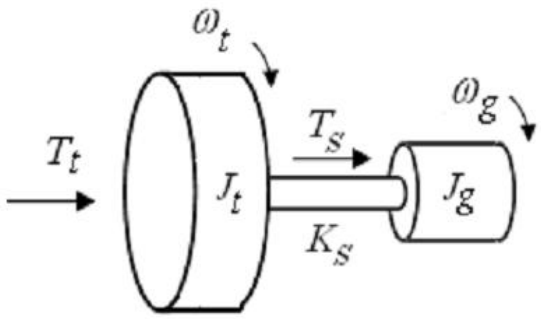


Fig. 4.4: Two mass model of wind turbine urbine train

where:

Tt : the mechanical torque referred to the generator side,

Te : the electromagnetic torque,

Jt : the equivalent turbine-blade inertia,

Jg : the generator inertia,

ω t: the turbine's rotational speed,

ω g: the generator's rotational speed,

K: the shaft stiffness

θs : the angular displacement between the ends of the shaft

4.1 EFFECT OF UPFC AND STATCOM DURING FAULT

Throughout An downstream deficiency condition, expansive issue ebbs and flows stream through those UPFC What's more STATCOM in front of those operation of the circuit board. This will make those voltage at PCC on drop, which acquires those shunt inverter of UPFC and STATCOM under operation. In this case, a security framework ought disengage the UPFC.

Furthermore, whether not controlled properly, those UPFC Furthermore STATCOM may Additionally help this PCC voltage hang Throughout the payment transform of the out absent voltage, disturbed attack those shortcoming circumstances. In this body of evidence electrical

torque abruptly deceases with zero because of those voltage drop toward those iga terminal and the rotor velocity begins should expansion Throughout those fault, STATCOM can't prevent those sudden demise dip in the voltage and the destabilizing electrical torque In this way it can't restore those voltage toward those PCC of the pre deficiency level then afterward deficiency freedom. After clearing fault, the shunt inverter for STATCOM injects sensitive energy that serves with recuperate those voltage toward those PCC.

UPFC goes about as an expansive virtual inductance in arrangement with those line. Regulating the UPFC Similarly as An virtual inductor also guarantee zero genuine control absorption, minimizing those anxiety in the dc join Throughout An issue. On the different hand, the UPFC plans on build the voltage at those terminals of the WECS Furthermore thereby mitigates the destabilizing electrical torque What's more control Throughout those issue. Also, the shunt inverter from claiming UPFC injects sensitive control following shortcoming clearance, serving those recuperation for PCC voltage.

STATCOM

The basic configuration of the STATCOM adopted in this work is shown in Fig. 4.5.

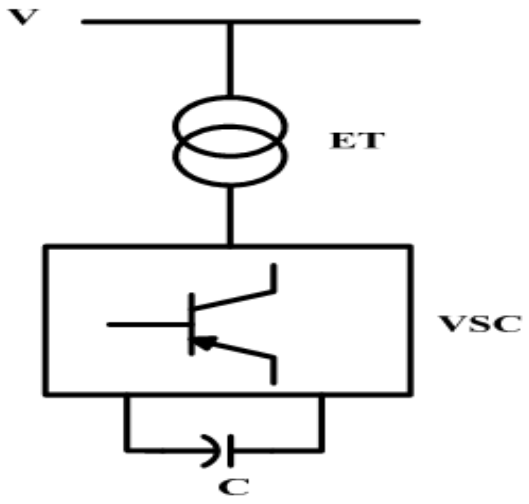


Fig. 4.5: Schematic diagram of basic STATCOM

The voltage-source converter (VSC) is the basic electronic part of a STATCOM, which converts the dc voltage into a set of three-phase output voltages with desired amplitude, frequency, and phase.

UPFC

Flexible AC Transmission Systems (FACTS) based power electronic converters like the UPFC are being used extensively in power Systems because of their ability to provide flexible power flow control . A schematic of the UPFC is shown in Fig. 2. It consists of two voltage source inverter (VSI). One is a shunt VSI and the other is series VSI. The shunt and series VSI are connected via a DC link, which includes a DC capacitor (C). The shunt converter of UPFC controls the connected UPFC bus and DC capacitor voltage . The series converter of UPFC controls the line active and reactive power flow by injecting a series voltage of adjustable magnitude and phase angle.

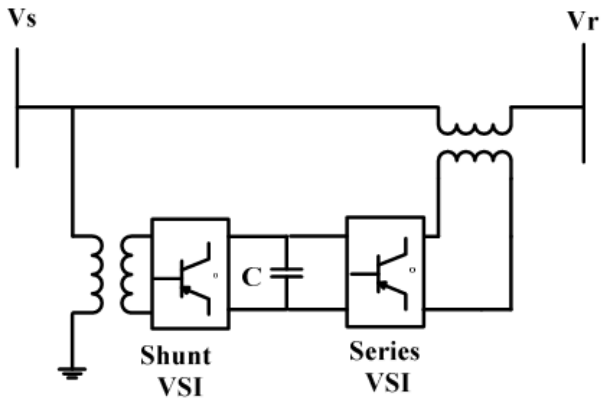


Fig. 4.6: UPFC schematic diagram

Fixed Speed Wind Turbine

Fig. 4.7 shows the schematic diagram of a typical WECS. The wind speed model, the model of wind turbine, the mechanical model of the drive-train and induction generator are described in the following sections.

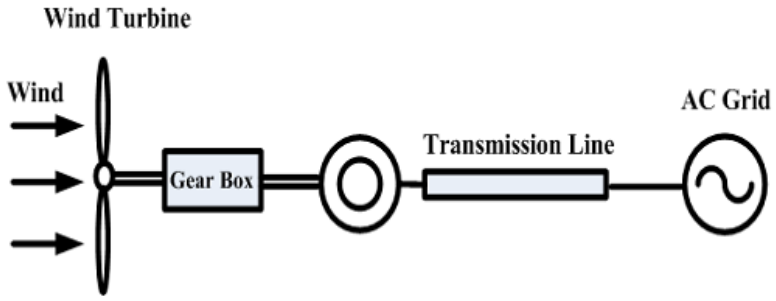


Fig. 4.7: Schematic diagram of typical WECS

4.2 CONTROL STRATEGY

Shunt Converter Control Strategy

The shunt converter of the UPFC and STATCOM controls the UPFC and STATCOM bus voltage/shunt reactive power and the dc link capacitor voltage .in the case ,the shunt converter voltage is decomposed into two components. One component is in-phase and the other is the magnitude of the UPFC and STATCOM bus voltage. De-couple control system has been employed to achieve simultaneous control of the UPFC and STATCOM bus voltage and the dc link capacitor voltage as shown in Fig. 4.8.

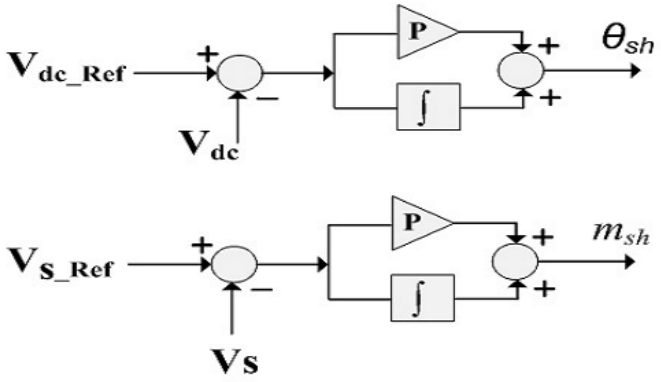


Fig. 4.8: UPFC and STATCOM shunt element control

Series Converter Control Strategy

The series converter of the UPFC provides simultaneous controls of real and reactive power flows in the transmission line [15]. To do so, the series converter injected voltage is decomposed into two components. One component of the series injected voltage is in quadrature and the other is in phase with the UPFC bus voltage. The quadrature injected component controls the transmission line real power flow. This strategy is similar to that of a phase shifter the in phase component controls the transmission line reactive power flow as shown in Fig. 4.9.

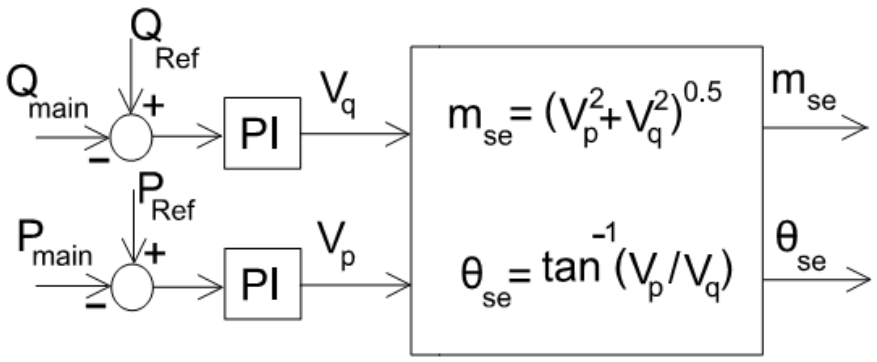


Fig. 4.9: UPFC series element control

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